PROCEEDINGS OF SCIENCE

Measurement of D^* photoproduction at three different centre-of-mass energies at HERA

Nataliia ZAKHARCHUK∗ **on behalf of the ZEUS Collaboration**
DESY
E-mail: nataliia.zakharchuk@desy.de

The cross sections for the photoproduction of $D^{*\pm}$ mesons have been measured with the ZEUS detector at HERA at three different ep centre-of-mass energies, $\sqrt{s}$, of 318, 251 and 225 GeV. For each data set, $D^{*\pm}$ mesons were required to have transverse momentum, $p_T^{D^*}$, and pseudorapidity, η^{D^*}, in the ranges $1.9 < p_T^{D^*} < 20$ GeV and $|\eta^{D^*}| < 1.6$. The events were required to have a virtuality of the incoming photon, Q^2, of less than 1 GeV^2. The dependence on $\sqrt{s}$ was studied by normalising to the high-statistics measurement at $\sqrt{s} = 318$ GeV. This led to the cancellation of a number of systematic effects both in data and theory. Predictions from next-to-leading-order QCD describe the $\sqrt{s}$ dependence of the data well.

XXII. International Workshop on Deep-Inelastic Scattering and Related Subjects
28 April - 2 May 2014
Warsaw, Poland

∗Speaker.

1. Introduction

Charm quarks in high-energy ep collisions at HERA are produced mainly through boson-gluon fusion (BGF) mechanism, where the exchanged virtual photon interacts with the gluon from the protons producing charm-anticharm pair. The high mass of the charm quark provides an opportunity to study perturbative QCD using the mass of the quark as a hard scale for the calculation that allows reliable predictions to be obtained.

Previous results on charm photoproduction were obtained at a single ep centre-of-mass energy. The dependence on the ep centre-of-mass energy is presented here for the first time. The variation of the cross section on the centre-of-mass energy should be sensitive to the gluon distribution in the proton. The mesurements of $D^{*\pm}$ cross sections are presented for three different centre-of-mass energies, $\sqrt{s}$ = 318, 251 and 225 GeV. The current analysis uses data collected with the ZEUS detector at HERA during the running periods of 2006 and 2007, when HERA operated with the energy of electrons E_e = 27.5 GeV and the energy of protons E_p = 920, 575 and 460 GeV. The appropriate samples are called high (HER), middle (MER), low energy runs (LER) and corresponded to an integrated luminosity of 144, 6.3 and 13.4 pb^{-1}.

In this measurement, the cross sections of $D^{*\pm}$ photoproduction at different $\sqrt{s}$ are normalized to the cross section with the highest statistics in order to cancel a number of systematic uncertainties both in data and theory.

2. Measurement of $D^{*\pm}$ in photoproduction

Photoproduction events were selected by requiring that no scattered electron with energy larger than 5 GeV was identified in the CAL [1]. The Jacquet-Blondel [2] method was used for reconstruction of W, $W_{JB} = \sqrt{2E_p(E-p_z)}$, using energy-flow objects (EFOs) [3]. The ranges $130 < W_{JB}^{HER} < 285$ GeV, $103 < W_{JB}^{MER} < 225$ GeV and $92 < W_{JB}^{LER} < 201$ GeV were used, where the lower cut was set by the trigger requirements and the upper cut was required to reject events from deep inelastic scattering. The ranges in W_{JB} correspond to the same y_{JB} range, $0.167 < y_{JB} < 0.802$.

The $D^{*\pm}$ mesons were reconstructed from the decay channels: $D^{*\pm} \to D^0\pi_s^{\pm}$ with $D^0 \to K^{\mp}\pi^{\pm}$. The $D^{*\pm}$ candidates were selected with transverse momentum $1.9 < p_T^{D*} < 20$ GeV and pseudorapidity $|\eta^{D^*}| < 1.6$. The mass difference $\Delta M \equiv M(D^*) - M(D^0)$ was used to extract the $D^{*\pm}$ signal. In order to estimate the contribution of combinatorial background, wrong charge combinations of kaons and pions, i.e. the same charge tracks, from D^0 decay were used. The distributions of ΔM for $D^{*\pm}$ candidates for the HER, MER, LER data periods are shown in Fig. 1.

The number of $D^{*\pm}$ mesons was obtained by subtracting the correct-sign background in the signal window $0.143 < \Delta M < 0.148$ GeV. The estimation of shape for correct-sign background was done by applying a simultaneous fit to the correct-sign and wrong-sign distributions, as outlined in a previous publication [4]. The fit was performed in the region $\Delta M < 0.168$ GeV. The region $0.140 < \Delta M < 0.150$ GeV was removed from the fit to the correct-sign distribution. The total signals are $N_{D^*}^{HER} = 12256 \pm 191$, $N_{D^*}^{MER} = 417 \pm 37$ and $N_{D^*}^{LER} = 859 \pm 49$ for the HER, MER and LER samples, respectively.

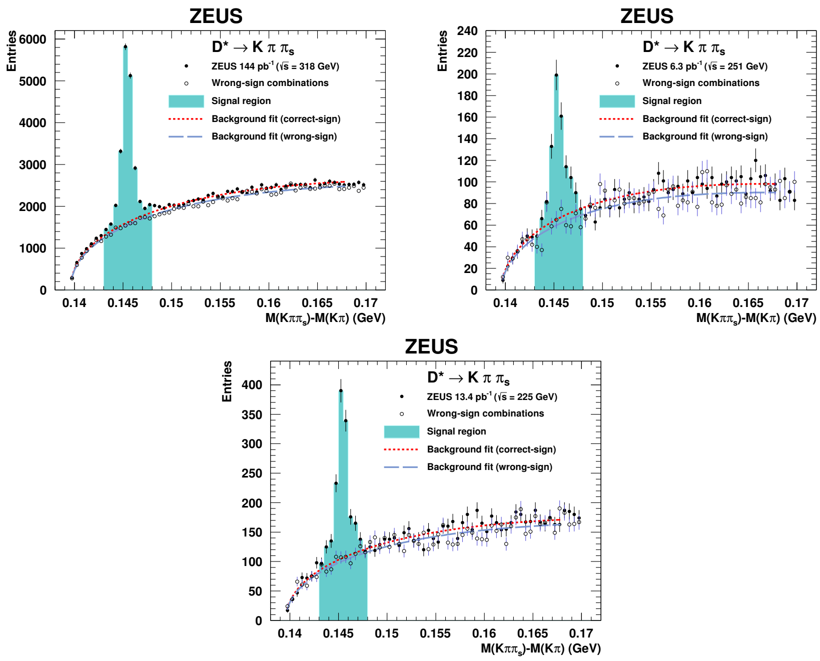

Figure 1: *Distribution of the mass difference $\Delta M \equiv M(D^*) - M(D^0)$, for $D^{*\pm}$ candidates for the HER ($\sqrt{s} = 318 GeV$), MER ($\sqrt{s} = 251 GeV$), LER ($\sqrt{s} = 225 GeV$) data samples. The candidates are shown for correct-sign (filled circles) and wrong-sign combinations (empty circles). The background fit is shown as a short-dashed (long-dashed) line for correct-sign (wrong-sign) combinations. The $D^{*\pm}$ signal region is marked as a shaded area.*

3. Determination of normalised cross sections

Visible $D^{*\pm}$ photoproduction cross sections are presented in the kinematic region $1.9 < p_T^{D*} < 20$ GeV, $|\eta^{D^*}| < 1.6$, $Q^2 < 1$ GeV^2 and $0.167 < y < 0.802$ and were calculated using the formula

$$\sigma = \frac{N_{data}^{D^*}}{L \cdot BR \cdot \alpha},$$

where $N_{data}^{D^*}$ is the number of $D^{*\pm}$ mesons in the data, BR is the product of the branching data fractions of the decay $D^{*\pm} \to D^0 \pi_s^{\pm}$ with $D^0 \to K^{\mp}\pi^{\pm}$ (BR = 2,63 ± 0,05% [5]), L is the integrated luminosity of the respective sample and α is the acceptance.

The MC samples of charm and beauty events used for the acceptance calculations were produced with PYTHIA 6.221 [6] generator. The comparison of the data and MC after correction is shown in Fig. 2, 3 and 4 for the HER, MER, LER samples. The MC gives a good enough description of the data to be used for the acceptance corrections.

The measured cross sections were normalised to the HER data sample:

$$R_{\sigma}^{HER,MER,LER} = \frac{\sigma_{visible}^{HER,MER,LER}}{\sigma_{visible}^{HER}}$$

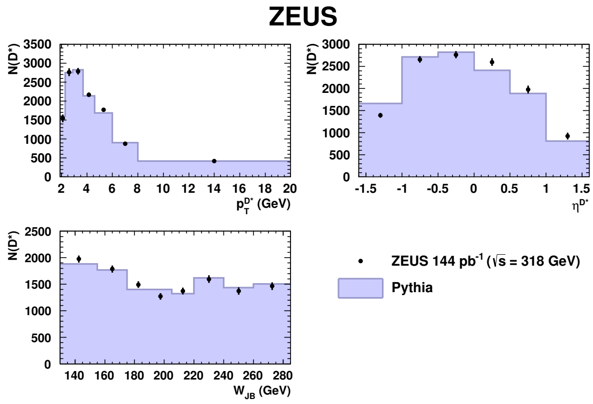

Figure 2: *Distributions of $p_T^{D^*}$,η^{D^*} and W_{JB} for $D^{*\pm}$ mesons in the HER ($\sqrt{s}$ = 318 GeV) data sample (points) compared with a mixture of charm and beauty events from the PYTHIA MC simulation (histogram).*

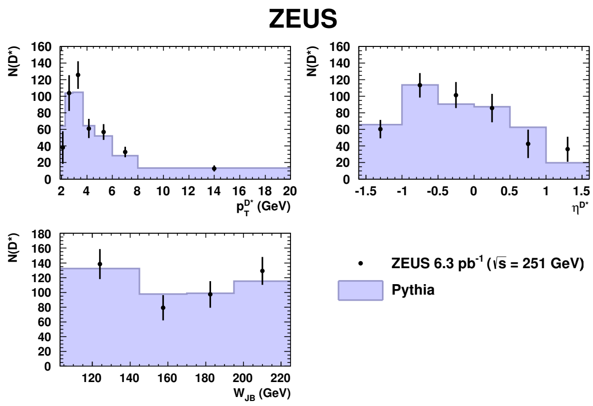

Figure 3: *Distributions of $p_T^{D^*}$, η^{D^*} and W_{JB} for $D^{*\pm}$ mesons in the MER ($\sqrt{s}$ = 251 GeV) data sample (points) compared with a mixture of charm and beauty events from the PYTHIA MC simulation (histogram).*

The measurement of ratios provided cancellation of several sourses of systematic uncertainties, both in data and theoretical predictions. This allows the study of the energy dependence of the cross section to higher precision. The total systematics are about ±5% in data and a few % in theory.

4. Comparison with QCD calculations

The measured ratios of the cross sections were compared to the NLO QCD calculation from Frixione et al [7]. The calculation is based on the massive scheme with the fixed number of active flavours. The structure-function parameterisations used in calculations were ZEUS-S 3-flavour FFNS [8] for the proton and GRV-G HO [9] for the photon. The renormalisation and factorisation scales were set to $\mu = \sqrt{m_c^2 + \hat{p_T}^2}$, where $\hat{p_T}$ is the average transverse momentum of the charm quarks and the pole mass was m_c = 1.5 GeV. The parameter, ε, in the Peterson fragmentation func-

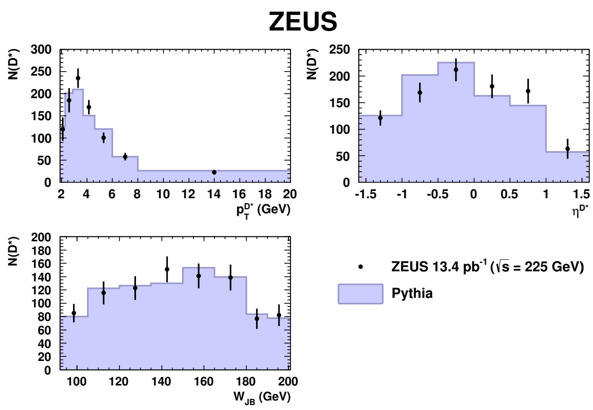

Figure 4: *Distributions of $p_T^{D^*}$, η^{D^*} and W_{JB} for $D^{*\pm}$ mesons in the LER ($\sqrt{s}$ = 225 GeV) data sample (points) compared with a mixture of charm and beauty events from the PYTHIA MC simulation (histogram).*

tion [10] was ε= 0.079 [11]. The uncertainties on the prediction were obtained through variation of the setting parameters.

The comparison of the data and the theory is shown in Fig. 5. The data increases with increasing *ep* centre-of-mass energy. This behaviour is predicted well by NLO QCD. The results shown here enhance confidence in the NLO QCD predictions for a future *ep* colliders with a higher energy.

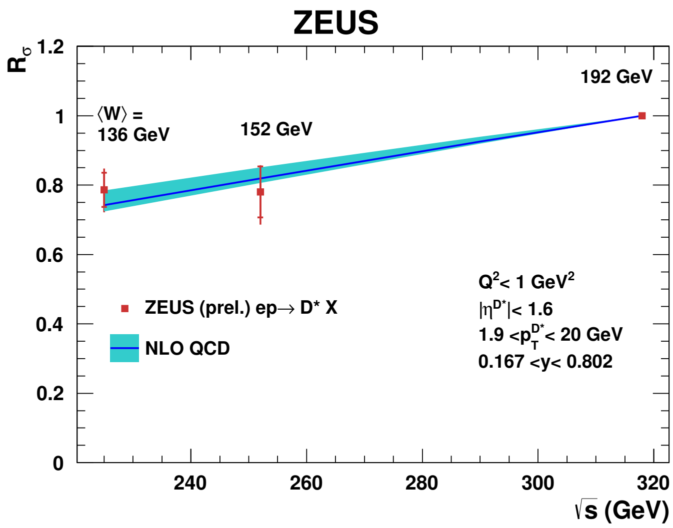

Figure 5: *Normalised $D^{*\pm}$ visible photoproduction cross sections as a function of the ep centre-of-mass energy. The data (points) are shown with statistical uncertainties (inner error bars) and statistical and systematic uncertainties added in quadrature (outer error bars). The predictions from NLO QCD (line) are shown with the uncertainties.*

5. Conclusion

The energy dependence of the ratio of the cross sections for $D^{*\pm}$ meson in photoproduction have been measured for the following kinematic region: $1.9 < p_T^{D*} < 20$ GeV, $|\eta| < 1.6$, $Q^2 < 1$ GeV^2 and $0.167 < y < 0.802$, where the range in y corresponds to the photon-proton centre-of-mass energies of 130 < W < 285 GeV, 103 < W < 225 GeV and 92 < W < 201 GeV. The cross section increases with increasing $\sqrt{s}$; this is well predicted by NLO QCD calculations.

References

[1] ZEUS Collab., M. Derrick et al., Phys. Lett. **B 322**, 287 (1994).

[2] F. Jacquet and A. Blondel, *Proceedings of the Study for an ep Facility for Europe*, U. Amaldi (ed.), p. 391. Hamburg, Germany (1979). Also in preprint DESY 79/48.

[3] ZEUS Collab., J. Breitweg et al., Eur. Phys. J. **C 6**, 43 (1999); G.M. Briskin, Ph.D. Thesis, Tel Aviv University, Report DESY-THESIS 1998-036, 1998.

[4] ZEUS Collab., H. Abramowicz et al., JHEP **05**, 097 (2013).

[5] Particle Data Group, D.E. Groom et al., Eur. Phys. J. C **15**, 1 (2000).

[6] T. Sjöstrand, Comp. Phys. Comm. **82**, 74 (1994); T. Sjöstrand et al., Comp. Phys. Comm. **135**, 238 (2001).

[7] S. Frixione et al., Phys. Lett. **B 348**, 633 (1995); S. Frixione, P. Nason and G. Ridolfi, Nucl. Phys. **B 454** (1995).

[8] ZEUS Collab., S. Chekanov et al., Phys. Rev. **D 67**, 012007 (2003).

[9] M. Glück, E. Reya and A. Vogt, Phys. Rev. **D 45**, 3986 (1992); M. Glück, E. Reya and A. Vogt, Phys. Rev. **D 46**, 1973 (1992).

[10] C. Peterson et al., Phys. Rev. **D 27**, 105 (1983).

[11] ZEUS Collab., S. Chekanov et al., JHEP **04**, 082 (2009).